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Effect of Nitrogen, Phosphorous and Potassium Fertilizers on Growth of Stock Plants of *Tectona grandis* (Linn. f.) and Rooting Behaviour of Shoot Cuttings

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Summary

The experiment was conducted to study the effect of nitrogen (N), phosphorus (P) and potassium (K) fertilizers on the growth of stock plants and rooting behaviour of coppice shoot cuttings of teak (*Tectona grandis* Linn. f.). Different combinations of N, P and K were applied to teak seedlings grown in earthenware pots. Growth observations on seedlings were recorded. Thereafter the seedlings were coppiced and data on coppice shoot growth were recorded in the month of June, 8-weeks after coppicing. Treatment of N, P and K fertilizers promoted the growth of stock plants. The highest concentration i.e., N_{100ppm} + P_{100ppm} + K_{100ppm} caused maximum growth enhancement in terms of mean height, mean collar diameter and mean number of leaves produced on the stock plants. Fertilizers also increased the number of coppice shoots and their length. The coppice shoots were made into mono-nodal, leafy, softwood cuttings, which were treated with 2500 ppm NAA and planted for rooting in a mist chamber. Rooting data was recorded 45 days after planting. Application of fertilizer to the stock plants showed significant effect on per cent callusing, mean length of shoot per cutting, mean number of leaves per cutting, mean number of roots per cutting and mean length of root per cutting. NAA treatment to the shoot cuttings promoted per cent callusing and mean number of roots per cutting. Interactive effects of stock plant fertilization and NAA treatment on per cent callusing, mean length of shoots per cutting, mean number of roots per cutting and mean length of root per cutting were also significant.

Key words: Fertilizer, growth, cutting, rooting, teak.

Introduction

Teak (*Tectona grandis* Linn. f.) is one of the most prized tropical timbers and is used commercially in shipbuilding, fine furniture, door and window frames etc. due to its extraordinarily wood working qualities and durability. Teak, a tropical hardwood species, native to India, Myanmar, the Lao People's Democratic Republic and Thailand, has been also introduced to numerous countries in tropical Asia, Africa and America. Increasing demands of teak wood and its diminishing stocks in natural forests have necessitated establishment of intensively managed teak plantations over massive areas. To increase the profitability and to make teak plantation programmes commercially sustainable, it is imperative to employ superior quality planting material, besides best management practices. Efforts have already begun to develop suitable technologies for rapid mass production of superior quality clonal planting stock of teak and several techniques which include the traditional methods of rooting cuttings (HUSEN and PAL, 2000 and 2001; PLANISAMY and SUBRAMANIAM, 2001; HUSEN and PAL, 2003 a and b) and *in vitro* technologies (GUPTA et al., 1980; MASCARENHAS *et al.,* 1993) have been developed. None of these methods have been adopted for commercial production of teak as these suffer from one or other drawbacks. Recently, methods for teak cloning using leafy, softwood juvenile cuttings have been developed (HUSEN and PAL, 2003 b) which hold a lot of promise being rapid, cheap, easy, simple as well as exhibiting high success rates (PLANISAMY and SUBRAMANIAM, 2001; HUSEN and PAL, 2003 b and c). The method depends on establishment of a hedge garden of tested, superior clones of teak and their intensive management for production in massive number of healthy juvenile shoots, possessing high physiological potential for easy rooting. Optimization of fertilizer application is an important consideration in this regards as stock plant fertilization influences quality as well as rooting in many woody plants species (HAUN and CORNELL, 1951; PRESTON *et al.,* 1953; REUTHER and ROEBER, 1980). An optimum nutrient supply prior to the collection of cuttings has been suggested for successful rooting (STRYDONA and HARTMANN, 1960). However, despite the recognized significance of the relationship between mineral nutrition and adventitious rooting, the importance of various mineral nutrients in hedge garden management has neither been properly emphasized, nor understood, especially in case of tropical hardwoods.

Therefore, the present study was conducted to determine the effect of stock plant fertilization on growth and adventitious root formation in shoot cuttings of teak.

Materials and Methods

Experimental site and donor plants

The experiment was conducted at New Forest campus of Forest Research Institute (77° 52' 12" East longitude, 30° 20' 40" North latitude and 640 m altitude), Dehra Dun. The donor plants were raised in nursery beds using seeds collected from teak seed orchard at New Forest campus. These were maintained by regular watering and weeding under normal environment prevailing at New Forest campus. Complete protection was provided against diseases and insects by foliar spray with insecticides and fungicides, as and when required.

Potting media and seedling transplantation

Potting medium contained soil, sand and farmyard manure in the ratio of 2:1:1. The medium was filled in glazed earthenware pots (9" x 9") at 4.00kg medium per pot. Finally one germinated seedling was transplanted in each pot in the month of September, 1998.

Fertilizers treatment and experimental deign

The 27 combinations of N (urea contains 46% N), P (super phosphate contains 16% P) and K (muriate of potash contains 60% K) were made as shown in *Table 1*. These treatments (only N and K) were split four times. Thereafter, each split dose of N and K was given at two months intervals starting from first week of September, 1998 to first week of March 1999. However, full dose of P was mixed in each potting media thoroughly except control. The experiment included 3 plants per treatment and was replicated 5 times. It was laid on completely randomized deign (PANSE and SUKHATME, 1967).

Observations on seedlings growth

The growth observations viz., height (cm), collar diameter (mm), number of nodes, lateral branches and fully opened leaves were recorded on the stock plants in month of April, 1999.

Coppicing

The stock plants were cut back at a distance of 10.0 cm from soil, in the month of April, 1999. The cut-end was coated with Chaupatia paste, comprising mixtures of copper carbonate and red lead. The data on the number of coppice shoots and number of nodes were recorded 8-week after the coppicing of stock plants.

Table 1. – Details of fertilizer treatments given to teak seedlings.

Treatment No.	Concentration of N, P and K in ppm	Treatment No.	Concentration of N, P and K in ppm
F-1	$N_0+P_0+K_0$	F-15	$N_{50\,(6.52)}+P_{50\,(18.75)}+K_{100\,(10.00)}$
F-2	$N_0+P_0+K_{50\,(5.00)}$	F-16	$N_{50\,(6.52)}+P_{100\,(37.50)}+K_0$
F-3	$N_0+P_0+K_{100\,(10.00)}$	F-17	$N_{50\,(6.52)}+P_{100\,(37.50)}+K_{50\,(5.00)}$
F-4	$N_0+P_{50\,(18.75)}+K_0$	F-18	$N_{50\,(6.52)}+P_{100\,(37.50)}+K_{100\,(10.00)}$
F-5	$N_0+P_{50\,(18.75)}+K_{50\,(5.00)}$	F-19	$N_{100\,(13.04)}+P_0+K_0$
F-6	$N_0+P_{50\,(18.75)}+K_{100\,(10.00)}$	F-20	$N_{100\,(13.04)}+P_0+K_{50\,(5.00)}$
F-7	$N_0+P_{100\,(37.50)}+K_0$	F-21	$N_{100\,(13.04)}+P_0+K_{100\,(10.00)}$
F-8	$N_0+P_{100\,(37.50)}+K_{50\,(5.00)}$	F-22	$N_{100\,(13.04)}+P_{50\,(18.75)}+K_0$
F-9	$N_0+P_{100\,(37.50)}+K_{100\,(10.00)}$	F-23	$N_{100\,(13.04)}+P_{50\,(18.75)}+K_{50\,(5.00)}$
F-10	$N_{50\,(6.52)}+P_0+K_0$	F-24	$N_{100\,(13.04)}+P_{50\,(18.75)}+K_{100\,(10.00)}$
F-11	$N_{50\,(6.52)}+P_0+K_{50\,(5.00)}$	F-25	$N_{100\,(13.04)}+P_{100\,(37.50)}+K_0$
F-12	$N_{50\,(6.52)}+P_0+K_{100\,(10.00)}$	F-26	$N_{100\,(13.04)}+P_{100\,(37.50)}+K_{50\,(5.00)}$
F-13	$N_{50\,(6.52)}+P_{50\,(18.75)}+K_0$	F-27	$N_{100\,(13.04)}+P_{100\,(37.50)}+K_{100\,(10.00)}$
F-14	$N_{50\,(6.52)}+P_{50\,(18.75)}+K_{50\,(5.00)}$		

N (urea contains 46% N), P (super phosphate contains 16% P) and K (muriate of potash contains 60% K); Values within parenthesis exhibited N, P and K treatments in gram.

Collection and preparation of cuttings

The coppice shoots were harvested in June, 1999. Each shoot was made into mono-nodal leafy soft-wood cuttings. Each cutting retained about 25.0 cm^2 leaf area per leaf and total length of cutting was about 4.0 cm which comprised of 1.0 cm internodal portion above the node and 3.0 cm below it. The cuttings prepared from coppice shoots taken from stock plants belonging to different treatments were kept in separate groups.

Treatments

The main treatments were (a) fertilizers and (b) NAA. As already mentioned, total 27 different combination of fertilizer treatments were given to stock plants (see *Table 1*). The cuttings were treated with 2500 ppm NAA (in talcum powder) and control (talcum powder only) maintained as described by HUSEN (2002).

Planting

After treatment the cuttings were planted in plastic trays, which were filled with sterilized vermiculite (pH 7.0). The vermiculite was presoaked in tap water for 24 hrs before filling it up in the trays. The cuttings were planted immediately after the treatment with auxin and were kept inside a mist chamber where the relative humidity was maintained at 85 ± 2 per cent and maximum and minimum day-night temperature at 32 ± 1°C to 26 ± 1°C respectively. Each treatment was replicated 5 times with 3 cuttings per replicate. The experiment was laid as per completely randomized design (PANSE and SUKHATME, 1967).

Observations on rooting response

After 45 days, the cuttings were carefully removed from the rooting medium and observations were recorded on callus formation, sprouting, rooting, number of sprouts per cutting and their length (cm), number of leaves per cuttings, number of roots per cutting and their length (cm).

Statistical analyses

All data were analyzed statistically using SPSS (Statistical Package for Social sciences) package. The data recorded in percentage were transformed to arcsine $\sqrt{p}$ value (ANDERSON and MCLEAN, 1974). However, other analyses were performed on untransformed data. The analysis of variance (ANOVA) procedures were used to test for significant effects of the treatments for the response variables measured. However, for the comparison of different means of different treatments, the critical difference (CD) was calculated based on the student t-test at 5 per cent probability.

Results

Effect of N, P and K application on growth of stock plants

The effect of N, P and K application on growth in height of stock plant was statistically significant at $P < 0.01$ level. The highest value of mean height (41.34 cm) was recorded in F 27 treatment, whereas F 1 showed the lowest value (25.65 cm) (*Figure 1*). N, P and K application had a significant effect ($P < 0.01$ level) on mean collar diameter. Maximum (8.87 mm) collar diameter was observed in F 27 treatment, while minimum (6.16 mm) in F 1. (*Figure 2*). Further, treatment of stock plants with N, P and K fertilizers had a significant effect on mean number of leaves per plant also. The highest value of mean number of leaves (8.60) was observed in F 27, which was however, statistically at par with F 23, F 24 and F 26 treatments. The lowest (6.20) mean number of leaves was recorded in F 19 (*Figure 3*). Effects of fertilizer, however, on mean number of nodes and lateral branches show insignificant effect at $P < 0.05$ level (data not shown).

Stock plants were coppiced at the age of 1-year to encourage the growth of coppice shoots and data is exhibited in *Figure 4* and *5*. Significant variation ($P < 0.05$ level) due to N, P and K application was observed for mean number of coppice shoots and their length. The maximum values for mean number of coppice shoots and mean coppice shoot length were recorded in F 27 and the minimum in F 1.

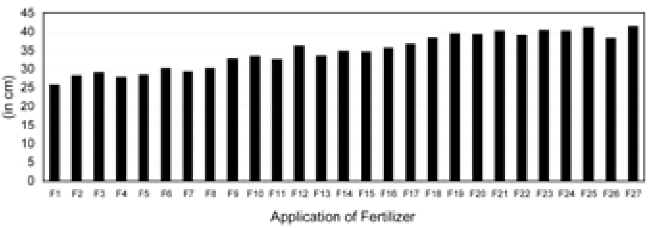

Figure 1. – Effect of N, P and K on mean height of stock plants (Critical difference at $P < 0.05$ level: 4.13).

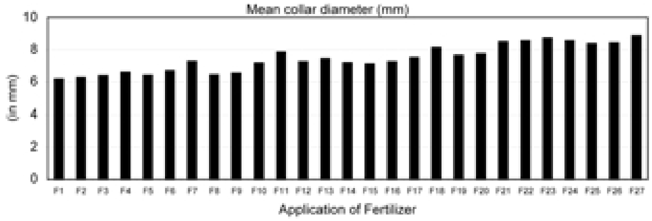

Figure 2. – Effect of N, P and K on mean collar diameter of stock plants (Critical difference at $P < 0.05$ level: 0.56).

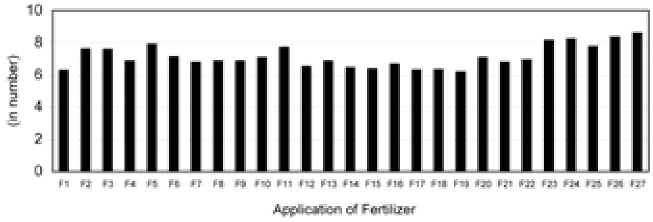

Figure 3. – Effect of N, P and K on mean number of leaves produced on stock plants (Critical difference at $P < 0.05$ level: 0.77).

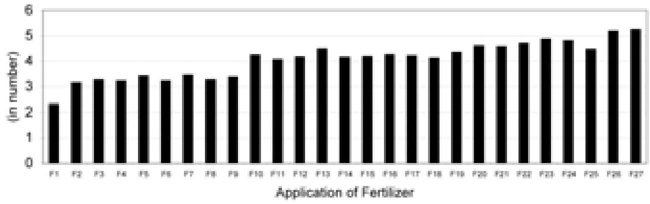

Figure 4. – Effect of N, P and K on mean number of coppice shoots produced on stock plants (Critical difference at $P < 0.05$ level: 0.45).

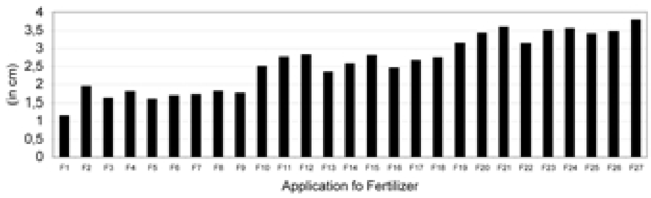

Figure 5. – Effect of N, P and K on mean length of coppice shoots produced on stock plants (Critical difference at $P < 0.05$ level: 0.47).

Effect N, P and K application on rooting of coppiced shoot cuttings

N, P and K application to stock plant exhibited significant effect on callus formations at the base of cuttings. The highest per cent callusing was caused by F 27 which was followed by F 12 and F 4 while, the other treatments did not show any callus formation and therefore no statistically significant response. NAA treatment significantly increased per cent callusing. Further, the combined effect of N, P and K application and NAA treatment was also significant. Maximum (20.00%) callus formation was observed in F 27 in combination with NAA (*Table 2*). Per cent rooting, sprouting and mean number of shoots per cutting did not exhibited any significant variation (*Table 2* and *3*). NAA treatment did not cause any significant response at <0.05 level on mean length of shoot per cutting. However, N, P, and K application to the stock plants exhibited significant effect on shoot growth. Maximum value of mean length of shoot per cutting was observed in F 27 treatment while, minimum in F 17. Further, combined effect of N, P and K application to the stock plant and treatment of coppice shoot cuttings with NAA exhibited a significant effect on shoot growth. F 27 X controls (NAA blanks) exhibited maximum value of mean length of shoot per cutting while the minimum value was recorded in F 17 X NAA (*Table 4*). N, P and K application to stock plant exhibited a significant effect on leaves production in coppice shoot cuttings. NAA treatment and two factor interaction effect between N, P, K application to stock plant and NAA treatment to cuttings did not produce any significant effect at $P < 0.05$ level (*Table 4*). Individual effects of N, P and K application to the stock plant and treatment of cuttings with NAA were significant at $P < 0.05$ level for mean number of roots per cutting.

Table 2. – Per cent callusing and per cent rooting in coppice shoot cuttings.

Treatment of N, P and K	Per cent callusing			Per cent rooting		
	Treatment of NAA (in ppm)		Mean	Treatment of NAA (in ppm)		Mean
	Control	NAA 2500		Control	NAA 2500	
F-1	0.00 (1.28)	0.00 (1.28)	0.00 (1.28)	60.00 (53.74)	53.33 (49.85)	56.67 (51.80)
F-2	0.00 (1.28)	0.00 (1.28)	0.00 (1.28)	60.00 (53.74)	66.67 (60.54)	63.33 (57.14)
F-3	0.00 (1.28)	0.00 (1.28)	0.00 (1.28)	40.00 (36.26)	46.67 (43.05)	43.33 (39.65)
F-4	6.67 (8.08)	0.00 (1.28)	3.33 (4.68)	46.67 (40.15)	66.67 (57.64)	56.67 (48.90)
F-5	0.00 (1.28)	0.00 (1.28)	0.00 (1.28)	60.00 (53.74)	53.33 (46.95)	56.67 (50.35)
F-6	0.00 (1.28)	0.00 (1.28)	0.00 (1.28)	66.67 (57.64)	66.67 (57.64)	66.67 (57.64)
F-7	0.00 (1.28)	0.00 (1.28)	0.00 (1.28)	86.67 (75.13)	60.00 (56.64)	73.33 (65.89)
F-8	0.00 (1.28)	0.00 (1.28)	0.00 (1.28)	53.34 (44.05)	73.33 (64.44)	63.34 (54.24)
F-9	0.00 (1.28)	0.00 (1.28)	0.00 (1.28)	66.67 (57.64)	66.67 (60.54)	66.67 (59.09)
F-10	0.00 (1.28)	0.00 (1.28)	0.00 (1.28)	73.33 (64.44)	46.67 (40.15)	60.00 (52.29)
F-11	0.00 (1.28)	0.00 (1.28)	0.00 (1.28)	66.67 (57.64)	66.67 (57.64)	66.67 (57.64)
F-12	0.00 (1.28)	13.33 (14.87)	6.67 (8.08)	46.67 (40.15)	40.00 (36.26)	43.33 (38.20)
F-13	0.00 (1.28)	0.00 (1.28)	0.00 (1.28)	60.00 (50.84)	40.00 (36.26)	50.00 (43.55)
F-14	0.00 (1.28)	0.00 (1.28)	0.00 (1.28)	66.67 (60.54)	53.33 (49.85)	60.00 (55.19)
F-15	0.00 (1.28)	0.00 (1.28)	0.00 (1.28)	60.00 (53.74)	53.33 (46.95)	56.67 (50.35)
F-16	0.00 (1.28)	0.00 (1.28)	0.00 (1.28)	53.33 (46.95)	60.00 (53.74)	56.67 (50.35)
F-17	0.00 (1.28)	0.00 (1.28)	0.00 (1.28)	53.33 (46.95)	13.33 (14.87)	33.33 (30.91)
F-18	0.00 (1.28)	0.00 (1.28)	0.00 (1.28)	33.33 (29.46)	53.33 (46.95)	43.33 (38.20)
F-19	0.00 (1.28)	0.00 (1.28)	0.00 (1.28)	60.00 (50.84)	53.33 (46.95)	56.67 (48.90)
F-20	0.00 (1.28)	0.00 (1.28)	0.00 (1.28)	86.67 (75.13)	53.33 (46.95)	70.00 (61.04)
F-21	0.00 (1.28)	0.00 (1.28)	0.00 (1.28)	40.00 (39.16)	53.33 (46.95)	46.67 (43.05)
F-22	0.00 (1.28)	0.00 (1.28)	0.00 (1.28)	93.33 (81.92)	53.33 (46.95)	73.33 (64.44)
F-23	0.00 (1.28)	0.00 (1.28)	0.00 (1.28)	86.67 (78.03)	60.00 (53.74)	73.33 (65.89)
F-24	0.00 (1.28)	0.00 (1.28)	0.00 (1.28)	53.34 (44.05)	60.00 (53.74)	56.67 (48.90)
F-25	0.00 (1.28)	0.00 (1.28)	0.00 (1.28)	66.67 (54.74)	53.33 (46.95)	60.00 (50.84)
F-26	0.00 (1.28)	0.00 (1.28)	0.00 (1.28)	60.00 (50.84)	53.34 (44.05)	56.67 (47.45)
F-27	0.00 (1.28)	20.00 (21.67)	10.00 (11.47)	73.34 (61.54)	53.3 3 (46.95)	63.34 (54.24)
Mean	0.25 (1.53)	1.23 (2.54)		61.98 (54.04)	54.57 (48.64)	
Source of variation	Fertilizer=*	NAA treat.=*	FertilizerX NAA treat.= *	Fertilizer=NS	NAA treat.=NS	Fertilizer X NAA treat.= NS
$CD_{(0.05)}$	3.62	0.99	5.13	-	-	-

Values within parenthesis are arc $\sin^{-1}$ transformed, * Significant at $P < 0.05$ level.

Table 3. – Per cent sprouting and mean number of shoots per cutting in coppice shoot cuttings.

Treatment of N, P and K	Per cent sprouting			Mean number of shoots per cutting in coppice shoots		
	Treatment of NAA (in ppm)		Mean	Treatment of NAA (in ppm)		Mean
	Control	NAA 2500		Control	NAA 2500	
F-1	60.00 (53.74)	53.33 (49.85)	56.67 (51.80)	1.00	0.80	0.90
F-2	40.00 (36.26)	40.00 (39.16)	40.00 (37.71)	0.80	1.00	0.90
F-3	66.67 (57.64)	73.33 (64.44)	70.00 (61.04)	1.00	1.00	1.00
F-4	66.67 (54.74)	66.67 (57.64)	66.67 (56.19)	1.00	1.00	1.00
F-5	60.00 (53.74)	66.67 (57.64)	63.33 (55.69)	1.00	1.00	1.00
F-6	66.67 (57.64)	66.67 (57.64)	66.67 (57.64)	1.00	1.20	1.10
F-7	73.34 (61.54)	60.00 (56.64)	66.67 (59.09)	1.00	1.00	1.00
F-8	53.34 (44.05)	73.33 (64.44)	63.34 (54.24)	0.80	1.00	0.90
F-9	66.67 (57.64)	66.67 (60.54)	66.67 (59.09)	0.80	1.00	0.90
F-10	86.67 (75.13)	53.33 (46.95)	66.67 (61.04)	0.80	0.80	0.80
F-11	66.67 (57.64)	66.67 (57.64)	66.67 (57.64)	1.00	0.80	0.90
F-12	66.67 (57.64)	80.00 (68.33)	73.33 (62.99)	0.80	1.00	0.90
F-13	60.00 (50.84)	66.67 (57.64)	63.34 (54.24)	1.00	1.00	1.00
F-14	66.67 (60.54)	53.33 (49.85)	60.00 (55.19)	1.00	0.80	0.90
F-15	60.00 (53.74)	53.33 (46.95)	56.67 (50.35)	1.00	0.80	0.90
F-16	53.33 (46.95)	60.00 (53.74)	56.67 (50.35)	0.80	1.00	0.90
F-17	53.33 (46.95)	53.33 (46.95)	53.33 (46.95)	1.00	0.80	0.90
F-18	53.33 (46.95)	53.33 (46.95)	53.33 (46.95)	0.80	0.80	0.80
F-19	60.00 (50.84)	53.33 (46.95)	56.67 (48.90)	1.00	0.80	0.90
F-20	80.00 (71.23)	53.33 (46.95)	66.67 (59.09)	0.80	0.80	0.80
F-21	53.33 (46.95)	53.33 (46.95)	53.33 (46.95)	1.00	0.80	0.90
F-22	86.67 (75.13)	53.33 (46.95)	70.00 (61.04)	1.00	0.80	0.90
F-23	73.33 (64.44)	73.33 (64.44)	73.33 (64.44)	0.80	1.00	0.90
F-24	53.34 (44.05)	60.00 (53.74)	56.67 (48.90)	0.80	1.00	0.90
F-25	66.67 (54.74)	53.33 (46.95)	60.00 (50.84)	1.00	0.80	0.90
F-26	60.00 (50.84)	53.34 (44.05)	56.67 (47.45)	0.80	0.80	0.80
F-27	73.34 (61.54)	73.34 (61.54)	73.34 (61.54)	1.00	1.00	1.00
Mean	63.95 (55.30)	60.49 (53.39)		0.92	0.91	
Source of variation	Fertilizer=NS	NAA treat.=NS	FertilizerX NAA treat.= NS	Fertilizer=NS	NAA treat.=NS	FertilizerX NAA treat.= NS
$CD_{(0.05)}$	-	-	-	-	-	-

Values within parenthesis are arc $\sin^{-1}$ transformed.

Table 4. – Mean length of shoot per cutting and mean number of leaves per cutting in coppice shoot cuttings.

Treatment of N, P and K	Mean length of shoot per cutting (in cm)			Mean number of leaves per cutting		
	Treatment of NAA (in ppm)		Mean	Treatment of NAA (in ppm)		Mean
	Control	NAA 2500		Control	NAA 2500	
F-1	4.73	3.30	4.02	2.00	4.00	4.33
F-2	3.25	3.75	3.50	4.67	2.20	2.10
F-3	2.98	2.45	2.72	4.33	4.53	4.43
F-4	4.37	2.37	3.37	5.00	4.00	4.50
F-5	2.63	4.45	3.54	5.20	4.53	4.87
F-6	2.03	3.62	2.83	3.07	5.32	4.19
F-7	3.28	4.00	3.64	4.07	5.07	4.57
F-8	1.88	2.22	2.05	3.20	3.53	3.37
F-9	2.62	4.30	3.46	3.77	4.47	4.12
F-10	1.45	1.13	1.29	2.47	2.00	2.23
F-11	1.49	1.58	1.54	2.50	3.40	2.95
F-12	3.53	5.50	4.52	4.87	6.32	5.59
F-13	2.83	3.71	3.27	3.90	5.83	4.87
F-14	2.56	3.37	2.97	4.20	4.13	4.17
F-15	3.18	1.23	2.21	3.33	1.60	2.47
F-16	1.25	1.52	1.38	2.67	3.80	3.23
F-17	1.40	1.06	1.23	2.80	2.66	2.73
F-18	4.30	4.33	4.31	4.07	4.67	4.37
F-19	2.73	1.94	2.33	4.00	2.60	3.30
F-20	2.24	1.95	2.09	3.27	3.00	3.13
F-21	1.68	2.03	1.85	3.40	3.07	3.23
F-22	2.38	1.73	2.05	4.00	3.33	3.67
F-23	2.28	4.06	3.17	3.07	4.26	3.67
F-24	2.75	3.92	3.33	4.00	5.06	4.80
F-25	2.95	1.60	2.78	5.50	2.40	3.95
F-26	2.33	2.25	2.29	4.40	4.40	4.40
F-27	8.50	5.39	6.95	6.87	6.13	6.50
Mean	2.91	2.92		3.87	3.96	
Source of variation	Fertilizer=*	NAA treat.=NS	FertilizerX NAA treat.= *	Fertilizer=*	NAA treat.=NS	FertilizerX NAA treat.= NS
$CD_{(0.05)}$	1.15	-	1.63	1.42	-	-

* Significant at $P < 0.05$ level.

Maximum value of mean number of roots per cuttings was observed in F 4 and F 5 treatments while, minimum in F 10 (*Table 5*). However, NAA treatment increased the mean number of roots per cutting. Further, the two factor interaction between N, P and K application to the stock plant and application of NAA treatment also exhibited significant effect at $P<0.05$ level. Maximum roots were observed in F 4 treatment X NAA while, minimum in F 17 X NAA (*Table 5*). N, P and K application to the stock plant had a significant effect on root growth. Maximum value of mean length of root per cutting was observed in F 11 treatment while, minimum in F 20. NAA treatment did not show any significant effect ($P < 0.05$ level) on root growth. However, combined effect between N, P and K application to the stock plant and treatment of cutting with NAA exhibited significant effect at $P < 0.05$ level. Maximum mean length of root per cutting was recorded in F 11 treatment X auxin untreated (NAA) cuttings while, minimum in F 17 X NAA treated cuttings (*Table 5*).

Discussion

Effect of N, P and K application on growth of stock plants

In the present investigation, application of N, P and K increased the growth of plants in terms of mean height, mean diameter and mean number of leaves. The highest concentration of N, P and K fertilizer i.e., $N_{100ppm} + P_{100ppm} + K_{100ppm}$ combination (F 27) was found to be the strongest treatment for stimulation of teak growth, because this treatment caused the maximum increase in mean height, mean collar diameter and mean number of leaves. There are many pervious reports showing the beneficial effect of N, P and K treatments on seedlings of forest tree species (AGRAWAL *et al.,* 1983; LIU *et al.,* 1994; OUIMET and FORTIN, 1992; CHANDLER and DALE, 1995; CARLSON and SOKO, 1999).

Furthermore, N, P and K treatment to the nursery stock of teak also produce significant effect on the coppicing ability in terms of number of coppiced shoots produced and their length. However, no published information is available on the residual effect of fertilizer application on coppice shoot growth in seedlings of teak or other tropical tree species.

Effect N, P and K application on rooting of coppice shoot cuttings

The findings show that teak cuttings exhibit differential fertilizer requirements for the different aspects of root and shoot growth on coppice shoot cuttings. Thus, the N, P and K treatments to stock plants did not effect per cent rooting, per cent sprouting and mean number of shoots per cutting. However, these treatments had a significant effect on mean length of shoot, mean number of leaves, mean number of roots and mean root length per cutting. The higher doses of N, P and K i.e., $N_{100ppm} + P_{100ppm} + K_{100ppm}$ caused maximum shoot elongation and production of maximum leaf growth on the cuttings. Mean number of roots per cutting and mean root length per cutting were also affected by N, P and K treatments to the stock plants but the different combination of N, P and K had a variable effect on these parameters.

Improvement of rooting of cuttings by stock plant fertilization in a number of tree species has been shown in several earlier reports also (see BLAZICH, 1988). An adequate mineral nutrition before and during rooting results into good rooting response (GOOD and TUKEY, 1967). However, REIN *et al.* (1991) have reported that hardwood cuttings of Rhododendron rooted best when stock plants were suboptimally fertilized resulting in less than maximal shoot growth. SAMISH and SPIEGEL (1957) have reported that the effect of P and K are beneficial only if optimum nitrogen levels for stock plant shoot growths are retained. But unbalanced fertilizers rich in nitrogen and low in P, K, and other nutrients have been found to increase rooting in *Prosopis alba* cuttings from stock plants (DESOUZA and FELKER, 1986). Therefore, different species and different types of cuttings may need different combination of mineral nutrients for optimal rooting.

The finding of this study show that fertilizer treatment to stock plants in teak have a beneficial effect on rooting coppice shoot cuttings but the effect of fertilizers on rooting and sprouting can not be assigned to any single nutrient. A balanced combination of several mineral nutrients only may lead to the desirable impact on the rooting of cuttings.

Table 5. – Mean length of shoot per cutting and mean number of leaves per cutting in coppice shoot cuttings.

Treatment of N, P and K	Mean number of roots per cutting			Mean length of root per cutting (in cm)		
	Treatment of NAA (in ppm)		Mean	Treatment of NAA (in ppm)		Mean
	Control	NAA 2500		Control	NAA 2500	
F-1	4.20	3.60	3.90	3.92	3.98	3.95
F-2	3.33	4.03	3.68	7.28	6.29	6.79
F-3	4.00	2.90	3.45	5.06	7.96	6.51
F-4	1.66	8.93	5.30	6.44	7.22	6.83
F-5	3.70	6.90	5.30	12.37	5.15	8.76
F-6	2.77	6.80	4.78	8.81	9.07	8.94
F-7	3.23	6.00	4.62	13.03	10.86	11.95
F-8	4.80	6.27	4.54	6.95	10.60	8.77
F-9	2.87	7.57	5.22	7.04	10.06	8.55
F-10	1.20	1.40	1.30	8.23	8.44	8.33
F-11	3.83	2.27	3.05	13.50	11.51	12.51
F-12	2.87	2.53	2.70	5.49	6.21	5.85
F-13	2.10	2.03	2.07	3.48	4.22	3.85
F-14	3.27	3.00	3.13	6.82	4.09	5.46
F-15	3.67	2.03	2.85	8.39	5.15	6.77
F-16	1.60	1.73	1.67	2.67	8.65	5.66
F-17	1.70	1.00	1.35	9.24	1.21	5.23
F-18	1.60	2.90	2.25	3.46	4.19	3.82
F-19	4.40	2.17	3.28	5.10	2.87	3.99
F-20	1.53	1.80	1.67	1.93	2.15	2.04
F-21	2.00	3.60	2.80	6.18	8.63	7.41
F-22	2.57	2.00	2.28	4.33	9.97	7.15
F-23	6.40	3.40	4.90	9.53	7.17	8.35
F-24	1.30	2.33	1.82	1.64	13.35	7.49
F-25	4.20	1.77	2.98	8.26	3.25	5.76
F-26	2.17	1.90	2.03	1.97	6.70	4.33
F-27	4.17	6.13	5.15	3.81	6.80	5.31
Mean	3.00	3.59		6.95	6.87	
Source of variation	Fertilizer=*	NAA treat.=*	FertilizerX NAA treat.= *	Fertilizer=*	NAA treat.=NS	FertilizerX NAA treat.= *
$CD_{(0.05)}$	1.56	0.42	2.20	3.27	-	4.63

* Significant at $P < 0.05$ level.

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Little Genetic Differentiation Within the Dominant Forest Tree, *Eucalyptus marginata* (Myrtaceae) of South-Western Australia

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Summary

Genetic diversity in the continuously distributed *Eucalyptus marginata* Donn ex Smith from south-western Australia was investigated using nuclear RFLP loci. Diversity was assessed in 15 populations from across the range of *E. marginata,* including the three morphologically recognised subspecies, and one population of the closely related *E. staeri.* Moderate levels of genetic diversity (H_T = 0.345) were detected in *Eucalyptus marginata* but there was little genetic structure and low differentiation between populations (θ = 0.034). Isolation by distance was observed, but there was differing influence of gene flow and drift over different spatial scales. There was no genetic support for the recognition of three subspecies, or the informal division of northern and southern forms recognised by foresters. Some populations showed a high fixation index most likely due to neighbourhood structure within populations. The lack of genetic structure and low population differentiation indicates that collection of germplasm for rehabilitation of forest sites following mining or *Phythophthora cinnamomi* infection, may be made at a regional scale.

Key words: Eucalyptus marginata, population differentiation, genetic diversity, gene flow.

Introduction

Eucalyptus marginata Donn ex Smith (jarrah) is a long-lived forest tree with a widespread distribution in the mesic areas of the south-west of Western Australia, where rainfall is greater than 600mm per annum (DELL and HAVEL, 1989). It occurs from 100km north of Perth to the south coast (*Fig. 1*), and outliers to the main distribution occur where there is increased water availability as runoff from large granite rocks, e.g. at Jilakin Rock, or by impeded drainage in the lower soil horizon, such as at Katanning and Mt. Lesueur (CHURCHILL, 1968). The species probably had a much larger distribution during wetter climatic periods in the past, and if rainfall was increased by 75 mm per annum the main distribution could be extended to include all the present outliers (CHURCHILL, 1968). *Eucalyptus marginata* lives for 300–400 years (DELL and HAVEL, 1989), and the ability to survive in the lignotuberous stage for up to 20 years (VAN NOORT, 1960) assists in survival through occasional summer droughts. It also has an extensive root system for survival in a nutrient poor environment, and has adventitious

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